RECENT SPECTROHELIOGRAPH RESULTS.

IN a previous number of this Journal (vol. lxix. p. 609, 1904), under the heading of "A New Epoch in Solar Physics," I gave an account of the magnificent work that Prof. Hale had recently been accomplishing at the Yerkes Observatory with his latest form of spectroheliograph, the instrument being worked in conjunction with the great 42-inch Yerkes refractor, which forms an image of the sun seven inches in diameter.

In the present article it is proposed to give a brief description of another instrument based on the same principle, an account of which was published by M. Janssen, and to indicate some of the results which have been obtained with it. This instrument has been at work at the Solar Physics Observatory during the past year, and in a recent communication to the Royal Astronomical Society I gave a more full account of it, to which reference can be made for more detailed information than is here given.

It is not necessary in this place to refer at any length to the principle which underlies the construction of a spectroheliograph, since this was referred to in the article above mentioned. It will suffice here to say, therefore, that the pictures produced by this new method of solar research give us photographs of the sun in monochromatic light, or in rays of any particular wave-length that is desired. Thus if we require to study the distribution of hydrogen on or around the solar disc we employ a line in the spectrum of hydrogen, if calcium a calcium line, or iron an iron line.

There are, however, several methods of using the spectroheliograph. This instrument may either be employed in conjunction with a large equatorial, in which the solar image is moved across the primary slit by means of the declination motor which moves at the same time and rate the photographic plate; or the primary slit, and with it the whole spectroheliograph, may be moved across the image formed at the focus of the equatorial. The first method is that adopted at the Yerkes Observatory, and the second that at Potsdam.

There is a further method in which a stationary solar image is formed by means of a siderostat and lens, and the spectroheliograph is mounted horizontally and moved in an east and west direction across this fixed image. Such a mode of procedure is that employed at South Kensington.

The advantage of the last mentioned arrangement is that there is no limit to the size or weight of the spectroheliograph; the uniform motion required can be easily and efficiently secured, and lastly this motion does not in any way affect the steadiness of the solar image under examination.

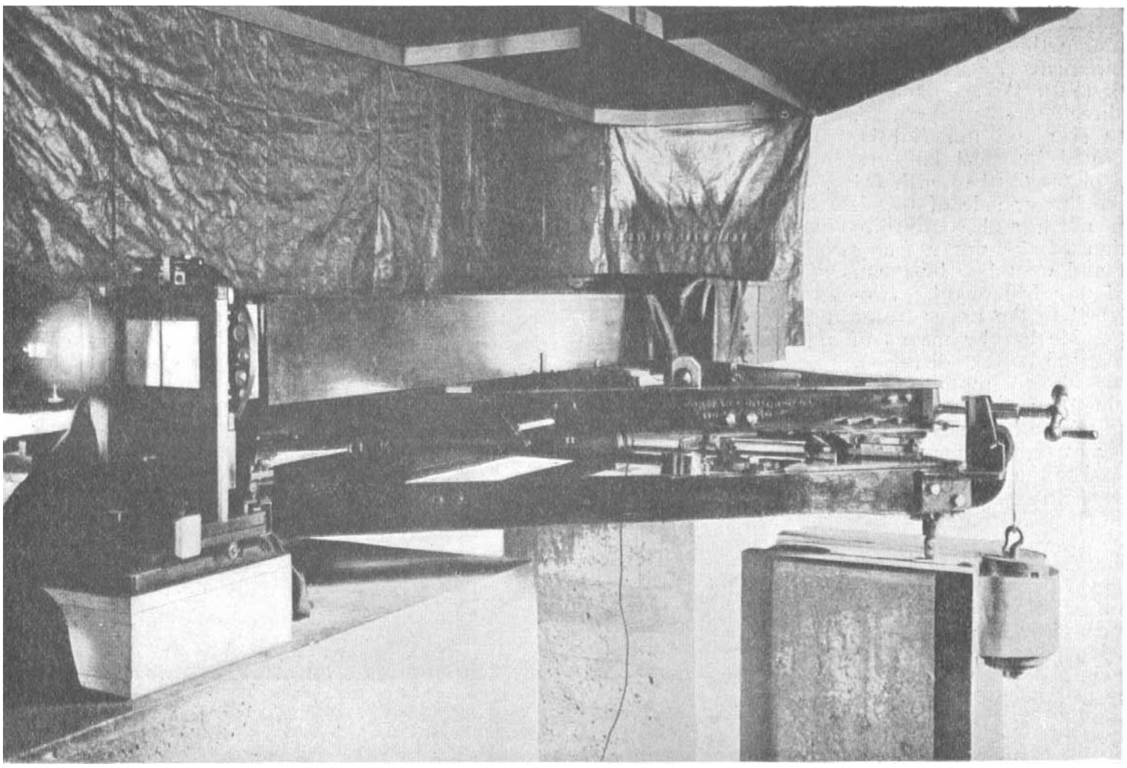


FIG. 1.—The spectroheliograph, showing the general arrangement of the two slits, the collimating and camera tubes, the moving (upper) and fixed (lower) triangular frameworks.

The South Kensington instrument was erected in the year 1903, but it was not until last year that satisfactory photographs were secured and routine work begun. This success was due to the use of a larger lens (12-inch) for throwing the solar image on the primary slit, the previous lens of 6 inches aperture not giving a sufficiently bright image.

In this curtailed description of the instrument reference of any length need only be made to the spectroheliograph proper. There is nothing particularly novel about the siderostat, except, perhaps, its more than usual size, the large mirror of 18 inches diameter, the two small motors for operating the slow motions in right ascension and declination, and a modified form of Russell control for regulating the speed of the driving clock. This instrument is

placed in a separate house the upper portion of which can be rolled back towards the north. Some distance due south of this, in another building, is the 12-inch Taylor photo-visual lens mounted on a concrete pillar, and still further south, and in the same building, is the spectroheliograph, also mounted on concrete pillars.

Wtih this arrangement the solar beam is thrown by the siderostat mirror continuously due south and in a horizontal direction; this beam then falls on the 12-inch lens, and the solar image in the focus of this lens is thrown on the primary slit plate of the spectroheliograph.

In order to analyse the solar image by allowing each portion of it to fall successively on the primary slit, the latter, and consequently the whole of the spectroheliograph, has to be moved horizontally in an east and west direction, a distance a little more than the diameter of the solar image (in this case 2½ inches). Further, this motion has to be extremely uniform.

The method adopted to accomplish both of these requirements is as follows:—A triangular iron framework (Fig. 1) is supported on three levelling screws on three concrete pillars. A second framework of the same size and material is placed on the first, but separated by steel balls free to roll between small steel plates fixed to each framework near the corners.

The longer side of this isosceles triangle is placed in a north and south direction. The direction of motion of the upper framework is restricted to an east and west line by means of a guide bar fixed to the lower framework; two small levers with rollers attached to the upper framework are pressed against this guide bar by means of small weights, thus ensuring the correct direction.

The actual motion of the upper framework is obtained by weights attached to one end of a steel strap the other end of which, after passing over a pulley mounted on an arm on the lower framework, is fixed to the western corner of the upper framework. This weight always tends to pull the upper framework towards the west, that is towards the right in Fig. 1.

The motion is controlled by a plunger projecting downwards from the upper framework operating a piston in a cylinder full of oil attached to the lower framework. The outlet valve can be so adjusted that any desired rate of motion can be obtained.

Owing to changes of temperature of the oil, different rates of movement can be obtained for any one reading of the micrometer head regulating the outlet valve. It is necessary, therefore, when making an exposure for a "disc" or "limb" picture to take the temperature of the oil into account. This is accomplished by employing a table, made from previous "runs," in which the valve setting can be directly read off from the temperature reading and the required length of exposure.

It is on the upper framework that the optical parts of the spectroheliograph are placed. These consist of a double tube carrying the two slits (Fig. 2) at the northern or siderostat end and the two lenses (4-inch) of equal focal length at the southern end. The dispersion is produced by a single prism of 60°, and a reflector is inserted in the system in order to make the total deviation of the beam 180°. Thus the part of the solar image which passes through the primary slit falls on the collimating lens, is reflected by the 6-inch mirror on to the prism, traverses the latter, and finally, after passing through the camera lens, is brought to a focus in the plane of the secondary slit in the form of a spectrum. By isolating any particular line in this spectrum by means of the secondary slit (Fig. 2) the solar image can be analysed in this wave-length.

For photographing the whole disc of the sun or its immediate surroundings with one exposure the lengths of the slits must be greater than the diameter of the solar image (2½ inches); in the present case they are 3 inches long. Further, owing to the fact that the lines in the spectrum are curved, the secondary slit jaws are curved to the same radius; this necessitates very accurate adjustment of the secondary slit on the line, and means are provided to facilitate such requirements.

In order to obtain a photographic record of the sun in monochromatic light, a fixed photographic plate is held by means of a wooden support as close to the secondary slit as possible (Fig. 2). In this way, as the primary slit moves over the stationary solar image, so the secondary slit traverses with equal speed the stationary photographic plate.

Up till now the secondary slit has usually been

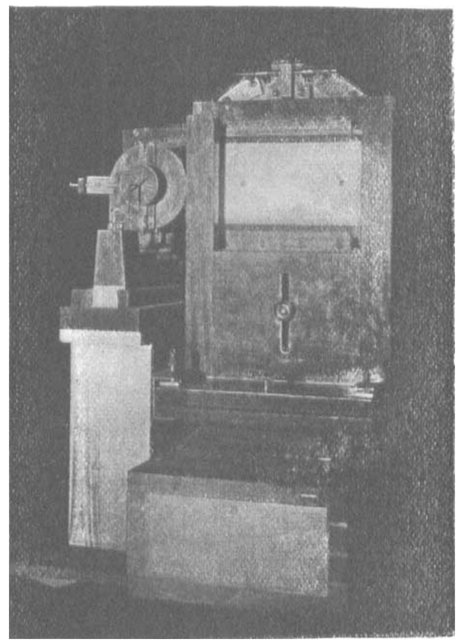


FIG. 2.—The primary slit is on the left and the secondary behind the plate carrier is seen on the right. This illustration shows also the metal disc in position for a "limb" exposure.

adjusted on the "K" line of calcium by eye estimation aided by a small watchmaker's lens, a check being made by taking a photograph of the spectrum, if possible with a sun-spot region, on the primary slit. On bright days this setting can be made with little difficulty, but during the late autumn, with a low sun, the "K" region of the spectrum is not easy to see, and the setting is in consequence very uncertain. A new method just brought into operation entirely eliminates this difficulty, for at a constant distance on the red side of the "K" line a small glass plate has been set with a cross engraved on its surface which can be adjusted on a known line in the more visible region of the spectrum. By bisecting a particular line with the cross the "K" line is adjusted on the slit jaw simultaneously.

The photographs taken during the past year have been of two kinds, the first to investigate the distribution and area of the calcium clouds, or flocculi as Prof. Hale has termed them, on the sun's disc, and

the second the distribution and forms of prominences round the limb. To obtain the latter, a metal disc just a little smaller than the solar image is placed close up to the primary slit plate (Fig. 2), and retained there by a metal wire fixed to a firm base; this disc is so adjusted that it is concentric with the solar image. While in use it becomes extremely hot, and it is therefore necessary that it be made of metal and riveted to the wire which supports it. These limb pictures, an example of which is given in Fig. 3, are of a composite nature in that after the exposure of the limb has been made the metal disc is removed from the primary slit, and a "disc" exposure is made on the same plate. It has been found by experience that a "limb" exposure requires about sixty times the time that is necessary for a "disc" exposure. Under very favourable conditions fifteen seconds is necessary for the latter and fifteen minutes for the former.

Without entering into too minute details, the following brief summary of the more salient facts derived from a general survey of the photographs taken during the past year may be given.

Dealing with the "disc" pictures in the first instance, all of them show a "mottling" of very definite character extending from the equator to the poles. Nearer the equatorial regions this mottling seems to become exaggerated in size in patches, some of the interspaces becoming filled up, giving rise to the prominent flocculi, many of which clearly indicate the mode of structure. Fig. 3 gives an idea of their appearance in the photographs. It will be seen that there are frequently long streaky bright portions springing apparently from a central nucleus and having subsidiary ramifications. A three-legged formation is a very common type of structure in many of the photographs.

These flocculi, in the first instance, exist alone, but

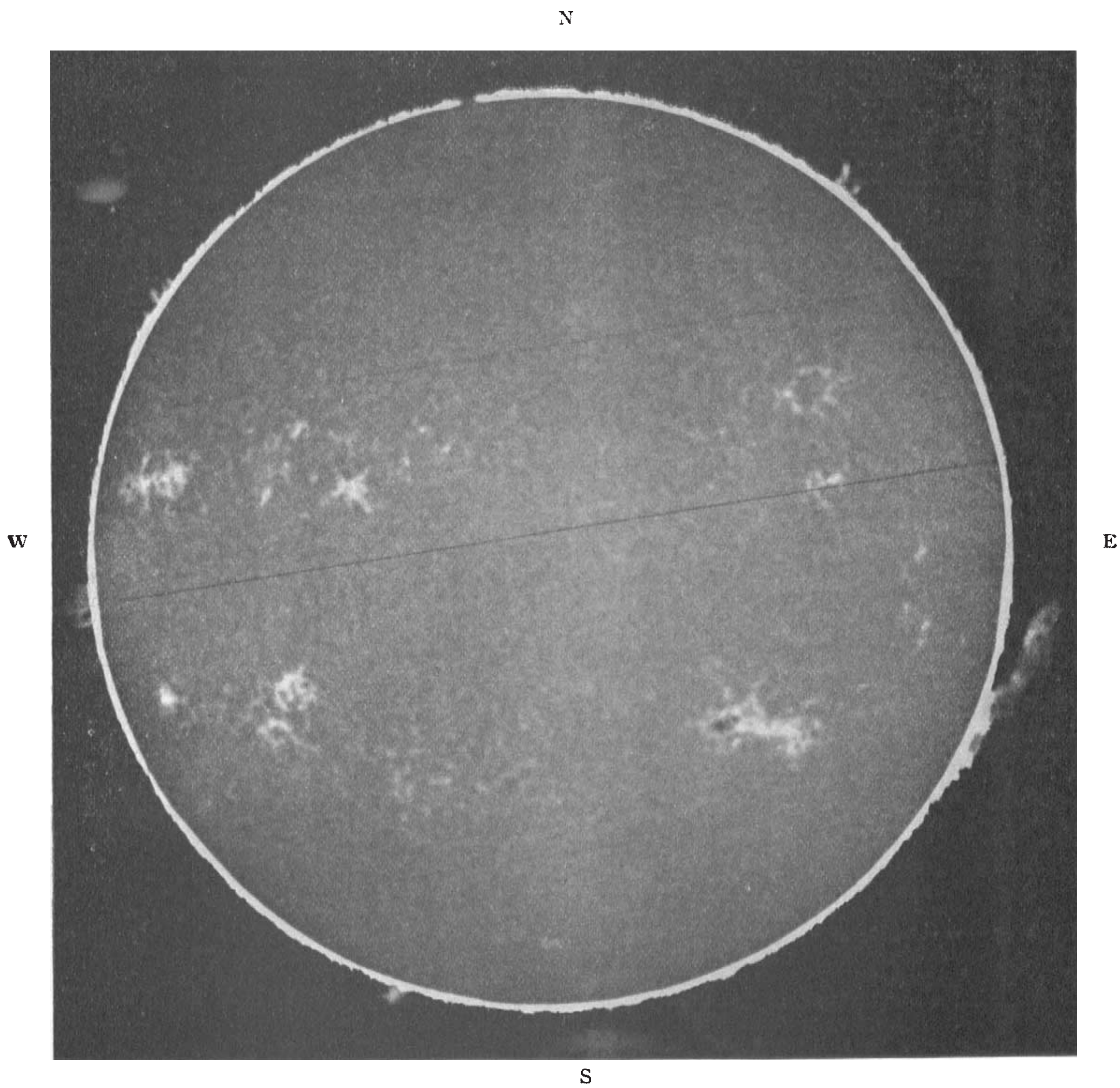


FIG. 3.—Limb and disc of sun in "K" light, July 19. Limb exposed rom 11h. 36m. to 11h. 52m. (interval 16m.); Disc exposed from 11h. 53m. 30s. to 11h. 53m. 48s. (interval 18s.). Enlarged nearly $2\frac{1}{2}$ times.

in some of them spots appear at a later stage. No spot has been photographed unaccompanied by a flocculus; in fact, the duration of a spot is only a brief interval in the life-history of a flocculus.

Another interesting subject of inquiry is the position of a spot in relation to the flocculus. Spots more generally make their appearance near the head of, or, in other words, precede the apparently trailing masses of the calcium clouds with respect to the solar rotation, which is from east to west. Some examples of these are given in Fig. 4. When there are two fairly large spots in one flocculus, the larger one nearly always precedes the smaller one.

The composite pictures (Fig. 3) showing the

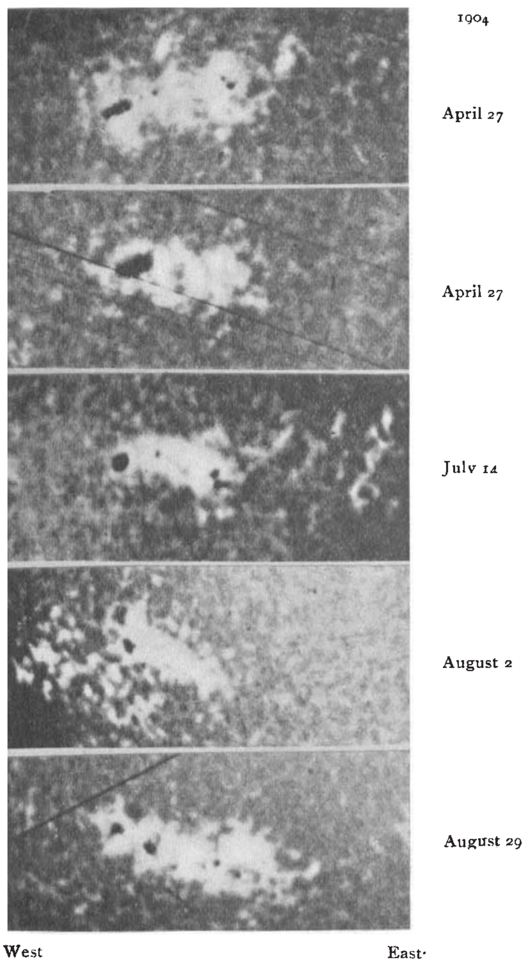
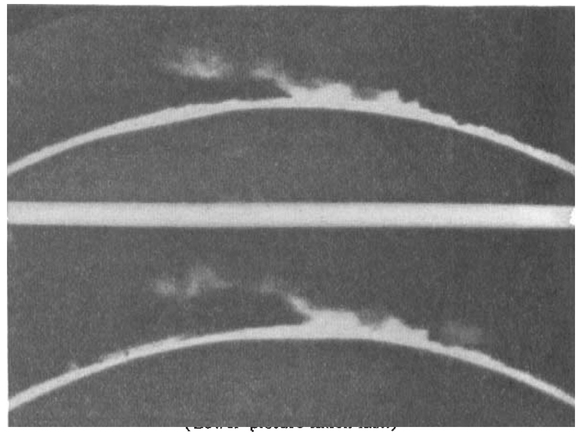


FIG. 4.—Typical cases of spots situated in the front portions of flocculi.

"limb" and "disc" have also brought to light many interesting points which call for further inquiry. In the first place prominences both near the solar poles and equator give strong images in calcium light. Secondly, prominences, which occur nearer the solar poles than the flocculi, do not appear to disturb the regular mottling on the disc in these high latitudes.

Again, an intense flocculus, when on the limb, is not always accompanied by a large prominence. These two last mentioned facts seem to indicate that flocculi and prominences are not always interdependent phenomena.

On continuous fine days, when several photographs of the limb are secured, an opportunity is afforded of studying the changes in the form of large prominences after intervals of a few hours. Two examples of such changes are here illustrated and briefly de-



scribed. In Fig. 5 we have two photographs (only the portions of the limb indicating the particular region of the sun in question are shown) which were taken on July 14, 1904, at 11h. 8m. a.m. and 12h. 8m. p.m. respectively. It will be noticed that during this interval of about one hour a startling change has occurred to the largest prominence; not only has its height been considerably increased, but its form has entirely changed. The material radiating the calcium light seems to have been ejected from the chromosphere and then to have apparently met a strong current moving polewards (that is, from left to right in the figure) which has thrown this material in that particular direction. The change of height from about 50,000 miles to 60,000 miles in this interval corresponds to a velocity of nearly three miles a second.

Not less interesting is the apparent disappearance of the second large prominence in the figure situated on the left.

Another example of a change of form of an enor-

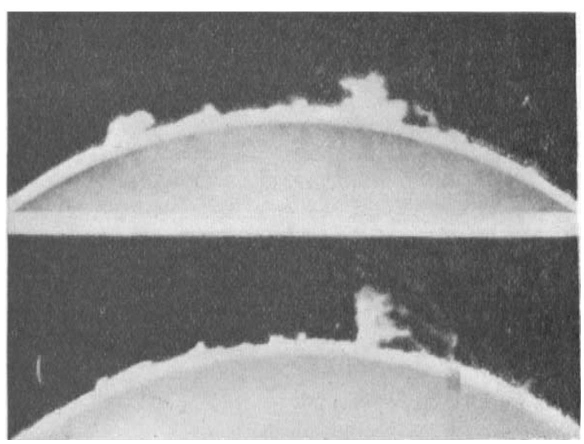


FIG. 6.—Two views of a large prominence taken with a four hours interval between them. (Lower picture taken last.)

mous prominence photographed on July 19 at 11h. 45m. a.m. and 3h. 59m. p.m. respectively is that shown in Fig. 6. This prominence was situated in the south-east quadrant. The approximate dimensions

as deduced from measurements of the photographs were as follows :—

Time h. m.		Length in miles		Height in miles
11 45	...	192,000	...	55,000
3 59	...	216,000	...	60,000

When it is mentioned that our earth has a diameter a little less than 8000 miles, an idea of the magnitude of this solar disturbance can be roughly grasped.

An interesting point to notice further in the original is the apparent falling towards the limb of the material forming the highest part of the prominence in the lower picture.

Enough, perhaps, has now been written to give the reader an idea of the instrument at work, and a few deductions from the photographs obtained during the summer months of the past year.

When it is considered that the results described, and others of which no mention has been made, only apply to the photographs secured with the "K" line of calcium, and that other lines in the solar spectrum, such as hydrogen, iron, magnesium, &c., still remain to be examined, some notion of the vast field of work open to investigators becomes apparent.

To avoid too much duplication of work beyond what is absolutely necessary, steps should be taken as soon as possible to subdivide the labour. The past year has seen the formation of a representative body to undertake such a scheme, and it is hoped that more instruments will soon be erected and at work to cope with the large demand of facts relating to our sun rendered now possible by the pioneer work of Prof. Hale and M. Deslandres.

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THE TEACHING VALUE OF MENAGERIES.[1]

SO far as the general public is concerned, there is always a very considerable danger lest menageries should be regarded merely as places of amusement and curiosity, and that their great value as teachers of zoology should be more or less completely ignored. The main object of the volume before us appears to be to emphasise the teaching value of institutions of this nature, and to show what admirable schools for acquiring the rudiments of practical zoology lie ready to our hand, if only we will take advantage of our opportunities; in other words, we have nature-teaching of a unique description awaiting our attention. Mr. Beddard treats, indeed, his subject almost exclusively from this point of view, so that his volume forms, in great degree, a sketchy kind of text-book of vertebrate zoology, illustrated by a number of first-class photographs and drawings of the animals under discussion. Such a mode of treatment necessarily prevents the inclusion of any great amount of matter that is really new in his work, and from one point of view it is a matter for regret that the author, with his long experience of the establishment in the Regent's Park, has not seen his way to give us more information with regard to the behaviour and life-history of animals in menageries. One point in this connection on which information is sadly lacking is the duration of life of animals in menageries, and the periods during which individuals of long-lived species have survived in captivity. So far as we have seen, information on this latter point is given only in two cases, namely, in that of the polar bear and that of the pelican. Possibly, however, the author may have in view a companion volume, in which these phases will form the leading theme; and if so, we feel sure that it will supply a marked want.

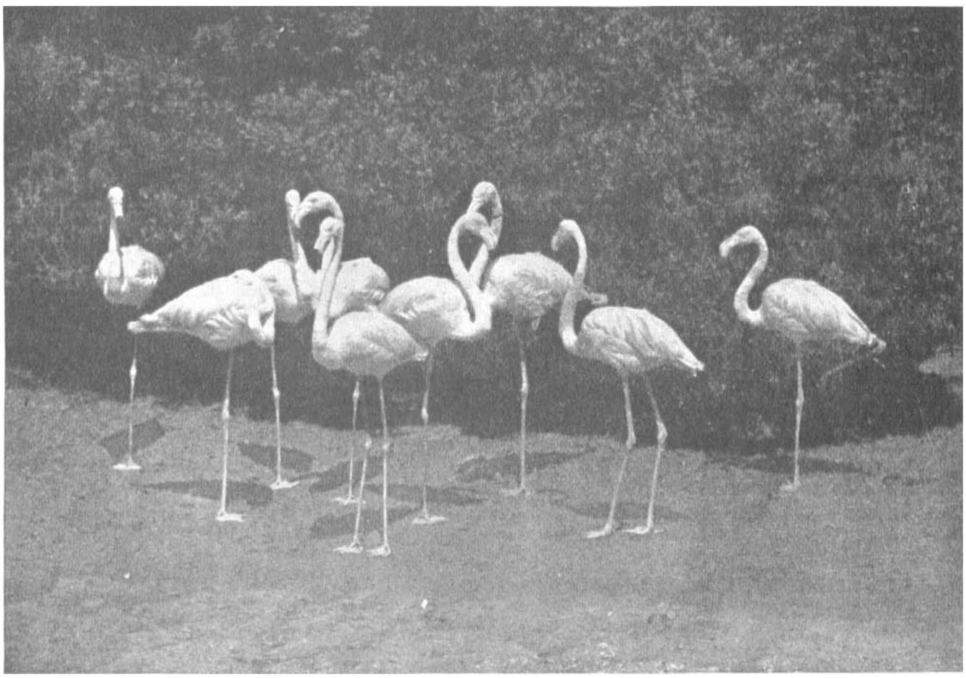

FIG. 1.—Flamingoes in the Regent's Park. From Beddard's "Natural History in Zoological Gardens."

Restricting, and very wisely so, his volume to the vertebrata, the author commences with a general sketch of the leading features of that group, and then takes in systematic order the various representatives selected for description. Mammals accordingly come first; and it is not out of place to mention that Mr. Beddard directs attention to the fact that a good popular name for this group is still a desideratum. In the case of both mammals and birds, the species taken as examples of different types are in the main well selected, and in nearly every instance the illustrations are almost everything that can be desired. As one of the best, among those reproduced from photographs, we have chosen the group of flamingoes, taken in the gardens, to set before our readers.

[1] "Natural History in Zoological Gardens; being some Account of Vertebrated Animals, with Special Reference to those usually seen in the Zoological Society's Gardens in London and Similar Institutions." By F. E. Beddard. Pp. x+310; illustrated. (London: Archibald Constable and Co., Ltd., 1905.) Price 6s. net.